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ROOT STUDIES II: Experimental Plan to Test the Effects of Soil Moisture, Certain Soil Nutrients, and Physical Injuries on Ponderosa Pine Development

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ROOT STUDIES II: Experimental Plan to Test the Effects of Soil Moisture, Certain Soil Nutrients, and Physical Injuries on Ponderosa Pine Development

W. D. Bedard

Contents

In the general field of study involving the factors which affect the health and vigor of ponderosa pine trees, most attention has been given to those concerned with biotic agents and climate. Although the potential importance of the physiologic and edaphic factors has not been overlooked, their study has been neglected through force of necessity. However, the part which each of these groups plays in causing high risk trees and high hazard areas or in maintaining normal conditions obviously must be known if a final solution to the western pine beetle problem is to be reached.

During the 1941 season, the Portland laboratory undertook the task of determining the effects of edaphic factors on ponderosa pine development. The object of this study is to determine the symptoms produced by varying nutrition, moisture, structure, and texture in the soil. Since this presupposes some root and crown deterioration, it was thought an excellent opportunity to study also the effects of certain mechanical injuries so that the tie-up could be made between effects of injury and effects of treatment. Thus, the ultimate aim of the study is to find explanations for as many as possible of the characters manifested by high risk trees.

Although this is the general plan, it is obvious that it could not be put into operation in its entirety during one field season so that it was necessary to limit the 1941 work according to the time and resources available. What then should be the scope of treatments for the first tests?

Choice of Treatments

Soil Treatments

Although great strides have been made in the use of irrigation and fertilizers in growing field crops, comparatively little is known as to the effect of such treatment on forest trees. Lodewick[38] found that irrigation and the use of fertilizers did not measurably affect the diameters of longleaf pine needles but did apparently cause increased needle length during dry seasons but not in years of normal rainfall. He also found that longer needles were produced on fertilized than on unfertilized soils, particularly where nitrogen-phosphorus mixtures were applied. Pessin[44] showed that a lack of any one of the seven mineral elements normally considered indispensable to plant growth produced symptoms in longleaf pine seedlings. Turner,[55] working with southern shortleaf pine, concluded that soil moisture dominates all other factors in governing root and shoot growth. Many writers[5 6 20 23 24 32 33 34 35 37 42] have shown the beneficial effect of precipitation on the growth of forest trees.

Even in the more generalized field of texture and structure of forest soils, comparatively little is known. Scholz[48] found that red and chestnut oak on the Black Rock Forest cove areas made more rapid growth on clay loam than on heavy clay loam or clay soils. Haasis[29] reported that on clayey soils the roots of ponderosa pine seedlings were longer and that the ratio between top and root was smaller than on loamy soils. He concluded that the greater the available moisture, the shorter the root and the greater is the ratio between top and root. Stephenson[50] pointed out that plants are profoundly affected by the physical properties of the soil on which they grow. Harper[31] found that in regions of restricted precipitation, fine textured soils were beneficial to tree growth, providing the soil particles were not too fine. He also reported that different tree species prefer different soil textures, and concluded that accurate knowledge of mechanical composition of the soil will help materially in determining where trees are more apt to grow if planted in regions of low rainfall.

Apparently then, forest trees, like other plants, are vastly affected by differences in the soil, and their reactions appear to be quite similar to those of crop plants. In choosing the materials for this experiment, therefore, the results secured with crop plants were used as the basis for making the choice. Water was the first choice because soil moisture is undoubtedly the most important single soil factor. Nitrogen was next chosen because high risk trees are notably deficient in crown volume and nitrogen is a well known producer of tops in plants. Phosphorus was the final choice because of its tendency to stimulate root production and its ability to produce resistance to insects and diseases.

Water was supplied to the watered plots at the rate of three gallons per week when needed—an amount sufficient to keep the soil well moistened. All fertilizers were applied at the rate of 200 pounds per acre—double the amount generally used for crop plants. Nitrogen was supplied in the form of barnyard manure, phosphorus in the form of bone meal, and a combination of the two in the form of ammonium-phosphate.

Injury Treatments

The effect on the plant of clipping the tops has been intensively studied. The work of Ellet and Carrier,[25] Aldous,[2] Parker and Sampson,[41] Sprague,[49] Biswell and Weaver,[9] Hiley and Cuncliffe[32-33] have shown the deleterious effects on the production of tops and roots of frequently clipping or otherwise removing tops. Craighead,[21 22] Swaine,[51] Evenden,[27] Graham,[28] and Harper[30] have shown the effect of defoliation by insects and fire in retarding or stopping cambial growth and in outright tree mortality. Balls[7] found that roots of cotton are often killed by a rising water table. Elliot[26] found the roots of corn were limited by high water table and the yield reduced. Bergman,[8] Cannon,[13] and Weaver and Clements[57] likewise state that poor soil aeration limits the root systems of plants. Pessin[43] and Sweet[52] found that roots were restricted by compact soil layers. Other factors observed to restrict roots are too great a hydrogen ion concentration reported by Addoms,[1] excess carbon dioxide found by Noyes and Weghorst,[40] too great acidity according to Taubenhaus and Ezekial,[53] and too great alkalinity observed by Weaver and Clements.[57]

Thus, natural injuries to both the crown and roots of trees can occur and result in decreased growth in certain regions. The question immediately arises concerning the cause of certain injuries apparent in high risk ponderosa pine trees and the sequence of deterioration following such injury. Can root injuries produce spike tops? What effects are produced by a dying terminal? Do such injuries affect the development of only one meristem or are root, shoot, cambial, and needle growth equally affected?

Hence, in choosing the injury treatments, the object was to cause mechanical injury to roots, leader, and general crown. Three degrees of root injury were selected: (1) Slight injury, comprising the removal of one or two main horizontal roots; (2) severe injury, comprising the removal of half of the main horizontal roots; and (3) tap-root injury, comprising removal of the main tap root immediately below the point of issuance of the main horizontals. Only one type of leader injury was chosen in which the last three years' terminal growth was removed to simulate the abrupt occurrence of a spike. Three degrees of foliage injury also were used: (1) Slight, 25 percent defoliation; (2) moderate, 50 percent defoliation; and (3) severe, 75 percent defoliation. Defoliation was accomplished by removing the desired percentage of twigs.

Choice of Trees and Area

In setting up this experiment, first consideration was given to the tree class to be treated and to the selection of trees for treatment. It was at once apparent that small trees must be used in order to permit accurate measurement of growth in cambium, leader, needles, and roots. To this end, 10-15 year old reproduction was selected as suitable. It was also apparent from the literature[47 56] that attempts to control soil moisture under field conditions were unsuccessful. To meet this objective, it was decided necessary to use small ponderosa pine seedlings in metal containers placed under some form of transparent roof to prevent wetting of the soil by rain and yet permit sunlight for the seedlings. For this portion of the experiment, the Forest Service very kindly provided 152 SIPI-O ponderosa pine seedlings from their Wind River Nursery. On October 12, 1941, these were planted in 30-pound berry cans sunk in the ground at Meryl Springs near Bly, Oregon. The soil for the cans was prepared by sifting and mixing a sufficient quantity of the local sandy loam to permit a homogeneous mixture in each can. The berry cans were lacquered inside and painted with asphalt paint on the outside to prevent corrosion during the course of the experiment. The potted seedlings were left uncovered during the winter of 1941-42 but will be roofed over with vita-pane in the spring of 1942 when the treatments will be applied. All cans are numbered and selection of trees for specific treatments will be randomized on an individual tree basis. The wilting coefficient and field capacity of the soil is being determined and the Soils Department of Oregon State College has kindly consented to make both mechanical and chemical analyses so that necessary information will be available when the treatments are started.

For the field tests with 10-15 year old reproduction, a suitable area was first selected. This was found on Section 23, T. 35 S., R. 14 E., where two and one-half acres of fairly uniform reproduction was located on a critical site. This proved to be site quality IV which had suffered a very severe loss from western pine beetle attack. A few standing snags are present, but the area is practically free of living mature trees. Dr. R. C. Hall of the Berkeley laboratory took a soil sample from this area to determine its wilting coefficient, and the Soils Department of Oregon State College is making both mechanical and chemical analyses so this information will be available if needed.

Once the area had been decided upon, suitable plots were chosen within the area. These comprised groups of reproduction containing at least 10 trees suitable for the test. Each plot was staked and numbered, and when a sufficient number had been selected, treatments were randomized on a plot basis.

Plan of Experiment

Both the reproduction plots and the potted seedling tests were planned on an analysis of variance basis. For the reproduction studies, treatments were selected as follows:

1. Water
2. Nitrogen
3. Phosphorus
4. Water + nitrogen
5. Water + phosphorus
6. Nitrogen + phosphorus
7. Nitrogen + phosphorus + water
8. Slight root injury
9. Severe root injury
10. Tap root injury
11. Leader injury
12. Defoliation 25%
13. Defoliation 50%
14. Defoliation ~~100%~~ 75%
15. No treatment

Thus with 15 treatments replicated three times, there are a total of 45 plots containing ten trees each, or 450 trees. It will be noted that the total number of possible treatments was not attained, because the injury treatments were not combined with the nutrient treatments, nor were they combined with each other where possible. These possible combinations were purposely omitted because they were not considered pertinent to the objective of the study, since the results were apt to be more confusing than enlightening.

In selecting the moisture treatments for the potted seedling tests, it was apparent from the work of Veihmeyer[56] and Schantz[47] that it would be impossible to maintain the soil moisture in the berry cans at a predetermined level less than the maximum capacity of the soil. These men found that water applied to soil in potometers was distributed rather evenly only as deep as the moisture was sufficient to wet the soil. Hence, all of the soil must be wetted completely and allowed to reach a certain minimum moisture content before being moistened again. On this basis, the treatments for the potted pine seedlings were selected tentatively as follows:

1. Moisture maintained at field capacity
2. Moisture maintained between field capacity and a point midway between the field capacity and wilting coefficient
3. Moisture maintained between field capacity and wilting coefficient
4. Moisture allowed to drop below wilting coefficient for 7-day periods
5. Moisture allowed to drop below wilting coefficient for 21-day periods
6. Nitrogen
7. Phosphorus
8. Six + seven
9. One + six
10. One + seven
11. One + six + seven
12. Two + six
13. Two + seven
14. Two + six + seven
15. Three + six
16. Three + seven
17. Three + six + seven
18. Four + six
19. Four + seven
20. Four + six + seven

21. Five + six

22. Five + seven

23. Five + six + seven

24. No treatment

25. Cans with soil but no seedlings to check evaporation

Thus, with five seedlings for each test and 25 tests, a total of 125 seedlings will be used. The extra 27 seedlings (152 were planted) will serve to take care of mortality and permit some selectivity before randomizing the treatments so that, as nearly as possible, comparable seedlings will be used for the tests.

A question may arise as to the need for duplicating the fertilizer treatments in these potted seedling tests. This was done for two reasons: (1) Roots are produced less abundantly in fertile soils and it is possible that under critical moisture conditions, these trees would succumb more rapidly than trees on less fertile soils; (2) it is possible that the addition of nutrients may change the wilting coefficient of the soil. For these reasons, it was deemed advisable to include nutrient treatments in order to ascertain the nutrient-moisture relationship.

Finally, the question arose as to what moisture treatment to use on the check seedlings and the straight nutrient applications (treatments 6, 7, 8, and 24). Two possibilities present themselves. Either these cans could be placed outside the shelter and permitted the normal precipitation, or they could be placed under the shelter and given an amount of moisture equal to the precipitation determined by daily measurements. Since the latter plan places all seedlings under the same conditions it appears to be the logical plan to follow.

Records

Reproduction Plots

When the reproduction plots were established certain records were made so as to have some basis for comparing the various growing points before and after treatment. These records were:

1. Length by years of last 5 years' leader growth (1936-40 incl.)

2. Length by years of last 4 years' needles (1937-40 incl.)

3. Average number fascicles per twig by years last 3 years (1938-40 incl.)

4. Total number fascicles per twig for 1940

Annual measurements of these same factors will be made to determine changes which may occur as a result of treatment. These four measurements will demonstrate changes in shoot growth, needle length, needle abundance, and needle retention--in other words changes in crown volume.

At the conclusion of the tests, sections will be taken from the top and bottom of each tree to determine annual increment before and after treatment. Each tree will also be preserved and dried to ascertain the ratio of dry weight of roots to dry weight of tops.

Potted Seedlings

Measurements were also made when the seedlings were potted for the controlled moisture tests. These records were the same for each seedling as follows:

1. Number of roots
2. Average length of roots
3. Total number of fascicles
4. Average length of needles
5. Total height

Annual measurements will be made of these same factors as in the reproduction plot studies, and the same final analysis of annual increment and ratio of root to top is also planned.

Growth Period Records

The growth period for the various meristematic tissues has an important bearing on this study, not only from the standpoint of knowing the period during which factors have their greatest influence, but also from the standpoint of determining the effect of soil moisture and nutrients on the duration of these growth periods. Periodic measurements will be made of shoot and needle elongation, radial growth, and root development throughout the duration of these studies. These records will be restricted to four of the reproduction plots to include one watered plot, one check plot, one nitrogen plus phosphorus plot, and one nitrogen plus phosphorus plus water plot. Shoot and needle elongation will be measured by means of a steel rule, radial growth by means of small calipers, and root elongation by a steel rule according to the method described by Reed.45/

Duration of Study

It is anticipated that two more seasons will be sufficient to complete these tests. That is, final measurements will be made in the fall of 1943. No repeat treatments are contemplated on the reproduction plots, or on the potted seedlings. No progress report will be submitted at the end of the 1942 season, but a final report will be prepared during the winter of 1943-44. This final report will be used as a basis for planning future work.

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